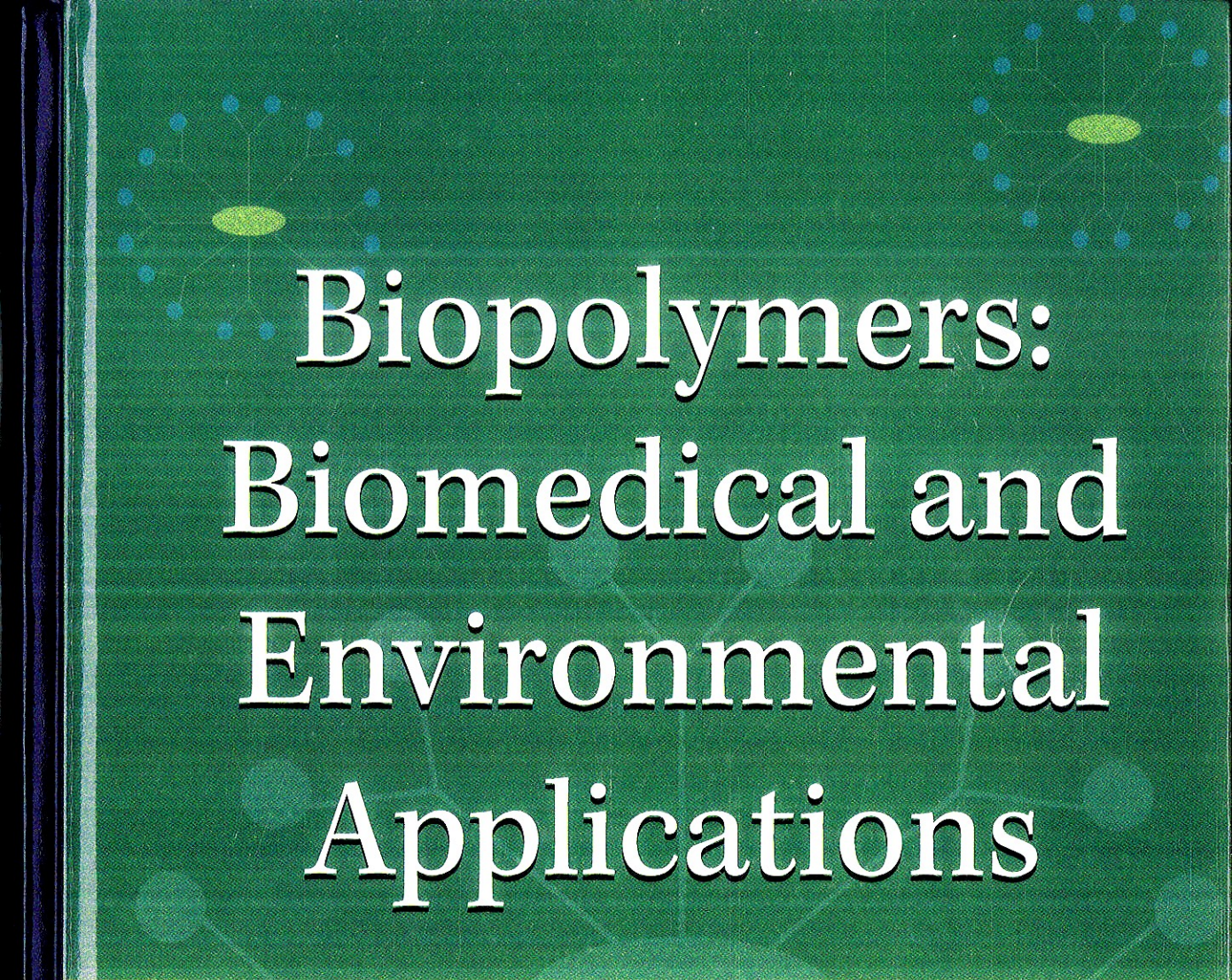




Biopolymers: Biomedical and Environmental Applications

Edited by Susheel Kalia and Luc Avérous

Contents

Preface	xvii
List of Contributors	xxi
Part 1: Polysaccharides	
1. Hyaluronic Acid: A Natural Biopolymer	3
<i>J. Schiller, N. Volpi, E. Hrabárová and L. Šoltés</i>	
1.1 Glycosaminoglycans	4
1.2 Hyaluronic Acid/Hyaluronan – Structure, Occurrence	7
1.3 Hyaluronan Synthases	8
1.4 Enzymatic Catabolism of Hyaluronan	10
1.5 Oxidative Degradation of Hyaluronan	11
1.5.1 Reaction of HA with HO• Radicals	13
1.5.2 Reaction of HA with HOCl	17
1.5.3 Reaction of HA with Peroxynitrite	18
1.6 Hyaluronan Degradation under Inflammatory Conditions	19
1.6.1 Generation of ROS under <i>In Vivo</i> Conditions	20
1.6.2 Discussion of ROS Effects under <i>In Vivo</i> Conditions	21
1.6.3 Cell-derived Oxidants and Their Effects on HA	22
1.6.4 Synovial Fluids	23
1.6.5 Extracellular Matrix	23
1.7 Interaction of Hyaluronan with Proteins and Inflammatory Mediators	24
1.7.1 HA Binding Proteins and Receptors	25
1.7.2 HA Receptors – Cellular Hyaladherins	25
1.7.3 Extracellular Hyaladherins	26
1.8 Hyaluronan and Its Derivatives in Use	26
1.8.1 Viscosurgery	27
1.8.2 Viscoprotection	27
1.8.3 Viscosupplementation	28
1.8.4 Vehicle for the Localized Delivery of Drugs to the Skin	28
1.8.5 Electrospinning for Regenerative Medicine	28
1.9 Concluding Remarks	29
Acknowledgements	29
References	30

2. Polysaccharide Graft Copolymers – Synthesis, Properties and Applications	35
<i>B. S. Kaith, Hemant Mittal, Jaspreet Kaur Bhatia and Susheel Kalia</i>	
2.1 Introduction	35
2.2 Modification of Polysaccharides through Graft Copolymerization	36
2.2.1 Graft Copolymerization Using Chemical Initiators	36
2.2.2 Graft Copolymerization Using Radiations as Initiators	38
2.3 Different Reaction Conditions for Graft Copolymerization	39
2.3.1 In Air (IA) Graft Copolymerization	39
2.3.2 Under Pressure (UP) Graft Copolymerization	39
2.3.3 Under Vacuum (UV) Graft Copolymerization	40
2.3.4 Graft Copolymerization Under the Influence of γ -Radiations	40
2.3.5 Graft Copolymerization Under the Influence of Microwave Radiations (MW)	40
2.4 Characterization of Graft Copolymers	42
2.4.1 FT-IR	42
2.4.2 ^{13}C NMR	42
2.4.3 SEM	44
2.4.4 XRD	44
2.4.5 Thermal Studies	45
2.5 Properties of Polysaccharide Graft Copolymers	46
2.5.1 Physical Properties	47
2.5.2 Chemical Properties	48
2.6 Applications of Modified Polysaccharides	49
2.6.1 Sustained Drug Delivery	49
2.6.2 Controlled Release of Fungicide	49
2.6.3 Selective Removal of Water from Different Petroleum Fraction-water Emulsions	50
2.6.4 Removal of Colloidal Particles from Water	50
2.6.5 Graft Copolymers as Reinforcing Agents in Green Composites	50
2.7 Biodegradation Studies	51
2.8 Conclusion	53
References	53
3. Natural Polysaccharides: From Membranes to Active Food Packaging	59
<i>Keith J. Fahnestock, Marjorie S. Austero and Caroline L. Schauer</i>	
3.1 Introduction	59
3.2 Polysaccharide Membranes	60
3.2.1 Permselective Membranes	61
3.2.2 Ionically Conductive Membranes	61
3.2.3 Polysaccharide Polymers	63

3.3	Permselective Membranes	63
3.4	Ionically Conductive Membranes	65
3.4.1	Cation Conductive Membranes	65
3.4.2	Anion Conductive Membrane	66
3.5	Polysaccharide Membranes: Synopsis	67
3.6	Active Food Packaging	67
3.7	Antimicrobial Films	68
3.7.1	Chitosan	69
3.7.2	Cellulose	76
3.8	Other Developments in Active Packaging: Lipid Barrier	77
3.9	Food Packaging: Synopsis	77
3.10	Conclusion	78
	References	78
4.	Starch as Source of Polymeric Materials	81
	<i>Antonio José Felix Carvalho</i>	
4.1	Introduction	81
4.2	Starch Structure	83
4.3	Non-food Application of Starch	86
4.4	Utilization of Starch in Plastics	87
4.5	Some Features of the Physical Chemistry of Thermoplastic Starch Processing	89
4.6	Recent Developments in Thermoplastic Starch	92
4.7	Reactive Extrusion	93
4.8	Conclusion	94
	Acknowledgement	95
	References	95
5.	Grafted Polysaccharides: Smart Materials of the Future, Their Synthesis and Applications	99
	<i>Gautam Sen, Ashoke Sharon and Sagar Pal</i>	
5.1	Introduction: Polysaccharides as a Material of the Future	99
5.2	Modified Polysaccharides	100
5.2.1	Modification by Insertion of Functional Groups onto the Polysaccharide Backbone	100
5.2.2	Modification by Grafting of Chains of Another Polymeric Material onto Polysaccharide Backbone	101
5.3	Characterization of Grafted Polysaccharides	110
5.3.1	Intrinsic Viscosity	110
5.3.2	Elemental Analysis	111
5.3.3	FTIR Spectroscopy	112
5.3.4	Scanning Electron Microscopy (SEM) Analysis	114
5.3.5	Thermo Gravimetric Analysis (TGA)	115

5.4	Application of Grafted Polysaccharides	117
5.4.1	Application as Viscosifier	117
5.4.2	Application as Flocculant for Water Treatment	119
5.4.3	Application as Matrix for Controlled Drug Release	121
5.5	Conclusion	124
	References	124
6.	Chitosan: The Most Valuable Derivative of Chitin	129
	<i>Debasish Sahoo and P.L. Nayak</i>	
6.1	Introduction	129
6.2	Polysaccharide	130
6.3	Sources of Chitin and Chitosan	131
6.4	Composition of Chitin, Chitosan and Cellulose	132
6.5	Chemical Modification of Chitin and Chitosan	134
6.6	Chitin – Chemical Modification	134
6.7	Chitosan – Chemical Modification	135
6.7.1	O-/N-carboxyalkylation	135
6.7.2	Sulfonation	136
6.7.3	Acylation	136
6.7.4	Sugar-Modified Chitosan	137
6.8	Depolymerization of Chitin and Chitosan	138
6.8.1	Chemical Methods	138
6.8.2	Physical Methods	140
6.8.3	Enzymatic Methods	140
6.8.4	Graft Copolymerization	141
6.8.5	Chitosan Crosslinking	142
6.9	Applications of Chitin and Chitosan	143
6.10	Bio-medical Applications of Chitosan	144
6.10.1	Gene Therapy	144
6.10.2	Enzyme Immobilization	144
6.10.3	Antioxidant Property	145
6.10.4	Hypocholesterolemic Activity	145
6.10.5	Wound-healing Accelerators	145
6.10.6	Artificial Kidney Membrane	147
6.10.7	Drug Delivery Systems	149
6.10.8	Blood Anticoagulants	151
6.10.9	Artificial Skin	152
6.11	Miscellaneous Applications	152
6.12	Antimicrobial Properties	154
6.13	Film-forming Ability of Chitosan	155
6.14	Function of Plasticizers in Film Formation	155
6.15	Membranes	156
6.16	In Wastewater Treatment	156
6.17	Multifaceted Derivatization Potential of Chitin and Chitosan	157
6.18	Conclusion	158
	References	159

Part 2: Bioplastics and Biocomposites

7. Biopolymers Based on Carboxylic Acids Derived from Renewable Resources	169
<i>Sushil Kumar, Nikhil Prakash and Dipaloy Datta</i>	
7.1 Introduction	169
7.2 Carboxylic Acids: Lactic- and Glycolic Acid	170
7.2.1 Lactic- and Glycolic Acid Production	171
7.3 Polymerization of Lactic- and Glycolic Acids	173
7.3.1 Polymerization of Lactic Acid	173
7.3.2 Polymerization of Glycolic Acid	178
7.4 Applications	180
7.5 Conclusions	181
References	181
 8. Characteristics and Applications of Poly (lactide)	 183
<i>Sandra Domenek, Cécile Courgneau and Violette Ducruet</i>	
8.1 Introduction	183
8.2 Production of PLA	184
8.2.1 Production of Lactic Acid	184
8.2.2 Synthesis of PLA	186
8.3 Physical PLA Properties	190
8.4 Microstructure and Thermal Properties	192
8.4.1 Amorphous Phase of PLA	192
8.4.2 Crystalline Structure of PLA	193
8.4.3 Crystallization Kinetics of PLA	194
8.4.4 Melting of PLA	197
8.5 Mechanical Properties of PLA	197
8.6 Barrier Properties of PLA	199
8.6.1 Gas Barrier Properties of PLA	199
8.6.2 Water Vapour Permeability of PLA	201
8.6.3 Permeability of Organic Vapours through PLA	202
8.7 Degradation Behaviour of PLA	203
8.7.1 Thermal Degradation	204
8.7.2 Hydrolysis	204
8.7.3 Biodegradation	206
8.8 Processing	208
8.9 Applications	210
8.9.1 Biomedical Applications of PLA	210
8.9.2 Packaging Applications Commodity of PLA	211
8.9.3 Textile Applications of PLA	214
8.9.4 Automotive Applications of PLA	215
8.9.5 Building Applications	215
8.9.6 Other Applications of PLA	216
8.10 Conclusion	217
References	217

9. Biobased Composites and Applications	225
<i>Smita Mohanty and Sanjay K. Nayak</i>	
9.1 Introduction	225
9.2 Biofibers: Opportunities and Limitations	226
9.2.1 Chemical Composition of Biofibers	228
9.2.2 Surface Modification and Characterization of Biofibers	232
9.2.3 Physical and Mechanical Properties of Biofibers	234
9.3 Biobased Composites: An Overview	235
9.3.1 Biobased Composites of Sisal Fiber Reinforced Polypropylene	237
9.3.2 Innovations in Biobased Hybrid Composites	246
9.3.3 Prototype Development and Future Recommendations	262
9.4 Conclusion and Future Prospects	262
References	263

Part 3: Miscellaneous Biopolymers

10. Cassia Seed Gums: A Renewable Reservoir for Synthesizing High Performance Materials for Water Remediation	269
<i>Vandana Singh and Pramendra Kumar</i>	
10.1 Introduction	269
10.2 Cassia Seed Gums Based Flocculants	271
10.2.1 <i>Cassia angustifolia</i>	272
10.2.2 <i>Cassia javahikai</i>	273
10.2.3 <i>Cassia tora</i>	276
10.2.4 Mechanism of Dye Removal by Flocculants	276
10.3 Cassia Seed Gums Based Metal Sorbents	277
10.3.1 <i>Cassia grandis</i>	278
10.3.2 <i>Cassia marginata</i>	280
10.3.3 <i>Cassia javanica</i>	283
10.4 Other Grafted Cassia Seed Gums	285
10.4.1 <i>Cassia pudibunda</i>	286
10.4.2 <i>Cassia occidentalis</i>	286
10.4.3 <i>Cassia siamea</i>	286
10.5 Conclusion	286
References	287
11. Bacterial Polymers: Resources, Synthesis and Applications	291
<i>GVN Rathna and Sutapa Ghosh</i>	
11.1 Introduction	291
11.2 Diverse Bacterial Species	295
11.2.1 Polysaccharides	295
11.2.2 Proteins	299
11.2.3 Protein-polysaccharide and Lipopolysaccharides	299
11.2.4 Polyesters	300

11.3	Methods to Obtain Bacterial Polymers	302
11.3.1	Conventional Methods (extraction/isolation)	302
11.3.2	Biosynthesis Methods	305
11.4	Tailor-made Methods	307
11.5	Applications	309
11.5.1	Biomedical Applications	309
11.5.2	Industrial Application	311
11.5.3	Food Applications	311
11.5.4	Agricultural Application	312
11.6	Conclusion and Future Prospective of Bacterial Polymers	312
	References	312
12.	Gum Arabica: A Natural Biopolymer	317
	<i>A. Sarkar</i>	
12.1	Introduction	317
12.1.1	Natural Gums, Sources and Collection	319
12.2	Chemistry of Gum Arabica	320
12.2.1	Potential Use as Material	321
12.3	Electroactivity of Gum	321
12.3.1	Ionic Conduction in Electroactive Material	322
12.3.2	Conduction Mechanism	323
12.3.3	Ion Transference Number	323
12.3.4	Conducting Ion Species in Gum Arabica	324
12.3.5	Carrier Mobility in Gum Arabica	324
12.4	Method of Characterization	325
12.4.1	Microscopic Observation	325
12.4.2	Microscopic Observations	326
12.4.3	Thermodynamic Analysis	328
12.4.4	Electrical Polarization and A.C. Conductivity	330
12.5	Electronic or Vibrational Properties	338
12.6	Enhancement of Electroactivity	342
12.7	Application Potential in Material Science	344
12.7.1	Gum Arabica and Its Scope of Application	344
12.7.2	Biopolymer Gel	345
12.7.3	Nanocomposites	351
12.7.4	Metallic Sulphide Nanocomplex of Gum Arabica	352
12.7.5	Development of Carbon Nanoparticle	356
12.7.6	Photosensitive Complex	359
12.8	Development of Biopolymeric Solar Cells	364
12.9	Biomedical-like Application	370
12.10	Conclusion	374
	Acknowledgements	374
	References	374
13.	Gluten: A Natural Biopolymer	377
	<i>S. Georgiev and Tereza Dekova</i>	
13.1	Introduction	378

13.2	Gliadins	383
13.2.1	Genetics and Polymorphism	384
13.3	Glutenins	387
13.3.1	Gluten Polymer Structure	388
13.3.2	Polymeric Proteins	389
13.3.3	Structure	391
13.3.4	Relationship to Wheat Quality	392
13.4	LMW-GS	393
13.4.1	Structure	395
13.4.2	Molecular Characterization of LMW-GS Genes	395
13.5	MALDI/MS: A New Technique Used to Analyze the Proteins in Plants	397
13.6	Albumins and Globulins	397
13.7	Wheat Gluten and Dietary Intolerance	398
13.8	Conclusion	399
	References	399
14.	Natural Rubber: Production, Properties and Applications	403
	<i>Thomas Kurian and N. M. Mathew</i>	
14.1	Introduction	403
14.2	Rubber Yielding Plants	404
14.3	History	404
14.4	Plantation Rubber	406
14.5	Rubber Cultivation	407
14.5.1	The Para Rubber Tree	407
14.5.2	Agro-climatic Requirements	408
14.5.3	Planting	408
14.5.4	Disease Control	408
14.5.5	Tapping and Collection of Crop	410
14.6	Biosynthesis of Rubber	412
14.7	Chemistry of Latex	413
14.8	Primary Processing	413
14.8.1	Preserved and Concentrated Latex	414
14.8.2	Ribbed Smoked Sheet	415
14.8.3	Pale Latex Crepe and Sole Crepe	418
14.8.4	Field Coagulum Crepe	418
14.8.5	Technically Specified Rubber	419
14.9	Current Global Status of Production and Consumption	421
14.10	Properties of NR	421
14.11	Blends of Natural Rubber	423
14.11.1	Blends of Natural Rubber with Thermoplastics	423
14.11.2	Preparation of Thermoplastic Natural Rubber	423
14.11.3	Properties and Applications of TPNR	423
14.12	Modified Forms of Natural Rubber	424
14.12.1	Introduction	424
14.12.2	Hydrogenated Natural Rubber	424

14.12.3	Chlorinated Natural Rubber	424
14.12.4	Cyclized Natural Rubber	425
14.12.5	Graft Copolymers Based on Natural Rubber	425
14.12.6	Epoxidized Natural Rubber	426
14.12.7	Ionic Thermoplastic Elastomers Based on Natural Rubber	427
14.13	Introduction to the Manufacture of Rubber Products	428
14.13.1	Processing Methods	429
14.13.2	Vulcanization Techniques	431
14.14	Applications of Natural Rubber	431
14.14.1	Dry Rubber Products	431
14.14.2	Latex products	432
14.15	Natural Rubber, a Green Commodity	432
14.16	Conclusions	433
	References	433
15.	Electronic Structures and Conduction Properties of Biopolymers	437
	<i>Mohsineen Wazir, Vinita Arora and A.K. Bakhshi</i>	
15.1	Introduction	437
15.2	Electronic Conduction in Proteins	438
15.2.1	Introduction	438
15.2.2	Investigations of Electronic Structure and Conduction Properties of Periodic and Aperiodic Polypeptides	439
15.2.3	Factors Affecting the Conduction Properties of Proteins	444
15.3	Electronic Conduction in DNA	447
15.3.1	Introduction	447
15.3.2	Mechanisms of Electron Transfer in DNA	447
15.3.3	Factors Affecting the Conductivity of DNA	448
15.3.4	Investigation of the Electronic Structure of DNA Base Stacks	448
15.4	Conclusions	453
	References	454

Part 4: Biopolymers for Specific Applications

16.	Applications of Biopolymers in Agriculture with Special Reference to Role of Plant Derived Biopolymers in Crop Protection	461
	<i>S. Niranjana Raj, S.N. Lavanya, J. Sudisha, and H. Shekar Shetty</i>	
16.1	Introduction	461
16.2	Biopolymers	462
16.3	Sources of Biopolymers	463
16.3.1	Plants	463
16.3.2	Microbes	464
16.3.3	Animals	466
16.3.4	Agricultural Wastes	466

16.3.5	Fossils	466
16.4	Application of biopolymers in agriculture	467
16.5	Seed coating for value addition	469
16.6	Plant Derived Biopolymers in Plant Growth Promotion	470
16.7	Plant Derived Biopolymers in Plant Disease Management	474
16.8	Integrated Use of Plant Gum Biopolymers	476
16.9	Transgenically Produced Biopolymers	477
16.10	Conclusions and Future Prospects	478
	References	479
17.	Modified Cellulose Fibres as a Biosorbent for the Organic Pollutants	483
	<i>Sami Boufi and Sabrine Alila</i>	
17.1	Introduction	483
17.2	Cellulose Structure	484
17.2.1	Molecular Level	484
17.2.2	Supramolecular Structure	485
17.2.3	Ultrastructure	486
17.3	Application of Natural Lignocellulosic Materials as Adsorbents for Organic Pollutants	488
17.4	The Use of Modified Cellulose Fibres as a Sorbent for the Organic Pollutants Removal	491
17.4.1	Adsorption of Model Organic Compounds on Surfactant Treated Cellulose Fibres	491
17.4.2	Different Strategies of Surface Chemical Modification of Cellulose Fibres	497
17.5	Adsorption Properties of Modified Cellulose Fibres	509
17.5.1	Adsorption of Herbicides	512
17.6	Adsorption Isotherm Modelisation	514
17.7	Thermodynamic Parameters	516
17.8	Adsorption Kinetic Modelling	516
17.9	Column Studies	519
17.10	Column Regeneration	519
17.11	Investigation of Adsorption Mechanisms by Laser Induced Luminescence	520
17.12	Conclusion	521
	References	522
18.	Polymers and Biopolymers in Pharmaceutical Technology	525
	<i>István Erős</i>	
18.1	Introduction	525
18.2	Purpose of the Use of Polymers in Pharmacy and Medicine	526
18.2.1	Active Substances	527

18.2.2	Bases for Preparations	528
18.2.3	Filling, Binding, Stabilizing and Coating Materials	528
18.2.4	Polymers Controlling Drug Release	529
18.3	Administration of Active Substances through the Mucosa of Body Cavities with the Help of Polymers and Biopolymers	547
18.3.1	Mucoadhesion	548
18.3.2	Mucoadhesive Preparations in the Gastrointestinal Tract	549
18.3.3	Drug Administration through the Nasal Mucosa	550
18.3.4	Mucoadhesive Preparations on the Mucosa of the Eye	551
18.3.5	Mucoadhesive Preparations in the Rectum and in the Vagina	552
18.4	Conclusion	553
	References	554
19.	Biopolymers Employed in Drug Delivery	559
	<i>Betina Giehl Zanetti Ramos</i>	
19.1	Introduction	559
19.2	The Most Studied Biopolymers in Drug Delivery	560
19.2.1	Cellulose Derivatives	561
19.2.2	Biopolymers from Marine Source	563
19.2.3	Others Polysaccharides	565
19.2.4	Polyhydroxyalcanoates	569
19.2.5	Biopolymers from Proteins	570
19.3	Conclusion	571
	References	571
20.	Natural Polymeric Vectors in Gene Therapy	575
	<i>Patit P. Kundu and Kishor Sarkar</i>	
20.1	Introduction	575
20.2	Cationic Polymers	577
20.3	Natural Polymers as Nonviral Vectors in Gene Therapy	578
20.3.1	Chitosan	578
20.3.2	Gelatin	592
20.3.3	Alginate	593
20.3.4	Arginine	594
20.3.5	Collagen	596
20.4	Conclusions	599
	References	599
	Index	605